The Plaice Box: evaluation studies

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Introduction

Bottom trawling is under much debate in Europe. Beam-trawling in particular is considered a destructive form of fishing for the seafloor and benthic communities living in the areas where it occurs. However, the effects of beam trawling on benthic communities could also lead to higher productivity of the ecosystem and hence more fish resources (van Denderen et al., 2013). It has been hypothesized that this mechanism may also be a driver in the plaice box – an area closed to fishing with large beam-trawlers – which has not resulted in its objective of protecting juvenile plaice and subsequent growth of spawning stock biomass. Detailed observations of recovery of habitats where fishing has been banned in continental shelve areas similar in structure and function as found in the plaice box, are lacking. As such, there is currently a void in understanding the role of fishing restrictions on ecosystem recovery and anticipated surplus production of fish resources within areas closed to fishing.

From 1989 onwards the plaice box has been partly closed to fishing vessels larger than 300HP with a full closure for such vessels since 1995. The impact on the ecosystem of this 25 year full closure to large fishing vessels is largely unknown. This is because no dedicated field monitoring study has taken place to verify the hypothesis of recovery/rebuilding of ecosystem components, such as benthic composition and biogeochemical functioning, under the absence of fishing by large bottom trawlers. A separate factsheet gives a summary of the objectives of the Plaice Box and the results of four evaluation studies (Amelot & Hintzen, 2022). This document describes the research needed to advice on the ecological function and effectiveness of the plaice box. The document was commissioned by the Dutch Ministry of Agriculture, Nature and Food Quality.

The proposed research consists of three phases:

1. Take a **snapshot** of the current condition and functioning of different ecosystem components, at small spatial scale, within the Dutch part of the plaice box outside the 12nm zone and adjacent areas that are, to date, still open to all trawlers.
2. Evaluate the **long-term** changes to ecosystem functioning under changes in fishing pressure over time in areas that have remained open and areas that were closed to large trawlers since 1995.
3. Prepare **advice** through ICES, including reflections of relevant stakeholders, that presents the trade-offs between nature conservation vs food security/socio-economic considerations.

Phase one, the snapshot research is needed to get an initial idea of the current state of the ecosystem in the area that has been closed for ~25 years. It is currently unclear whether this area is significantly different in ecosystem functioning compared to the adjacent areas that have remained open. It is also unclear whether there is indeed a surplus production of fish resources. The latter is often one of the

claimed beneficial aspects of marine protected areas. The results and interpretation on ecosystem functioning differences as obtained through phase one, will inform a discussion if pursuing the second phase will provide additional information that is essential to evaluate the impact of fishing on ecosystem functioning. This discussion, which will also include discussion with stakeholders, will be organised by the ministry. The decision to continue to phase two will be made by the ministry, though supported. Phase three will commence once phase two is completed.

Our recommendations in this document are based on discussions with stakeholders and scientists. The approach to the stakeholder consultation (fishers, representatives, NGOs and policy-makers) is described in Harkes & Steins (2022). The review of the different evaluations (Amelot & Hintzen, 2022), the outcomes of the stakeholder consultation (Harkes & Steins, 2022) and an inventory of existing data (Amelot, 2022) were then discussed in a workshop with scientists from different institutes and nationalities.

Area of interest

The area of interest is the plaice box outside the 12nm zone. Consultations of German and Danish government representatives indicate these countries do not to yet consider a re-opening of the plaice box. This suggests that a focus on only the Dutch part is most realistic (Harkes & Steins, 2022).

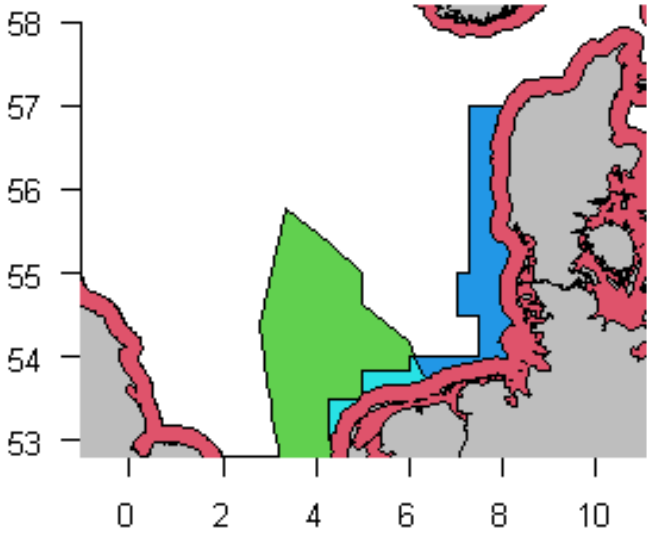

Figure 1. Area of the plaice box including the 12nm zone (in red), the plaice box outside the 12nm zone (in blue), the Dutch EEZ (in green) and the relevant study area outside the 12nm zone, within the Dutch EEZ and plaice box (in light blue).

Snapshot research

What function do we identify with each of these analyses

The functioning of ecosystem may pertain to several different aspects (benthic metabolism, carbon and nutrient cycling, food web functions etc.). However, in order to make a proper evaluation of the Plaice Box fisheries closure, a comparative study between areas in and outside the plaice box would be necessary to measure any relative differences between trawled and untrawled areas.

Sediment composition

The areas chosen for sampling must be comparable in terms of their habitat which can be assessed with knowledge of sediment grain size, bathymetry (depth), hydrodynamics or other important environmental aspects. Using a box corer, we will collect intact benthic samples from trawled and untrawled areas located along the border of the plaice box (inside vs. outside the trawl restricted areas) to evaluate the impact of trawling in adjacent habitats. Sediment core samples will allow us to observe differences between different sediment layers (recent trawling only affects the upper layers). We will collect samples in at least 10 locations along the plaice box border within the Dutch EEZ which would require (as a rule of thumb) 3 samples inside and 3 outside the restricted zone, equating to 30 sediment samples (10 locations * 3 inside * 3 outside = 60 box cores).

Box core samples will be subsampled using smaller cores which will be subdivided at 0–0.5, 0.5–1, 1–1.5, 1.5–2, 2–2.5, 2.5–3, 3–4, 4–5, 5–6, 6–8, and 8–10 cm depth intervals to collect sedimentary information at different layers. Median grain size, total organic carbon and nitrogen, and sediment pigments (chlorophyll-a, phaeopigments etc.) from these samples will allow the assessment of trawl effects on organic matter quantity and quality (Tiano et al., 2019, Rios-Yunes et al., in press).

Bioturbation

Bioturbation mostly pertains to physical sediment reworking by fauna while active burrow ventilationis known as 'bioirrigation' (Kristensen et a., 2012). These processes have strong links to several biogeochemical functions (Braeckmen et al., 2010). We will infer the effect of trawling on these processes by using the community bioturbation potential (BPc, Queirós et al., 2013) and bioirrigation potential (IPc, Wrede et al., 2018) indices which we will calculate from macrofaunal abundances and biomass. For this, data collected for benthic composition will be used to calculate the indices. *Benthic metabolism and nutrient cycles*

Oxygen consumption can be used as an indicator for the total community metabolism of the sediment (microbes and benthic fauna) which represents a balance between carbon fixation and oxidation (Soetaert et al., 1996). This also serves as a proxy for how biogeochemically 'active' certain sediments are. Information on nutrient cycling will be obtained through sediment incubations to gain oxygen/nutrient flux data. Samples for incubations will be collected by subsampling box core samples using 14 cm diameter subcores. The incubation cores with sediment and fauna will be 'incubated' by placing them into a thermostatic bath for 24 – 36 hours and measuring the oxygen and nutrient levels over time (Tiano et al,. 2020). Porewater nutrients will also be collected with an additional box core subsample. Porewater rhizon samplers will then be used to collect nutrient samples from 0, 1, 2, 3, 5, 7, and 10 cm depths inside the sediment (Seeberg-Elverfeldt et al., 2005; Tiano et al,. 2019). Information on denitrification, total mineralization, and nutrient removal functions will be calculated using mass budget modelling with information taken from the flux data (Soetaert et al., 2001; Tiano et al., 2022).

Benthic composition

Benthic samples will be used to illustrate differences in development of the benthic community, in terms of sensitivity and recoverability (Beauchard et al. 2022) as well as the empirically derived longevity distribution of the benthic community under a regime with/without trawling pressure in the past 40 years. From the box corer samples, sediments will be sieved through a 0.1 mm mesh to collect benthic macrofauna which will be preserved in 8 % formalin. Benthic species will be identified to the lowest possible taxonomic group and biomass and abundance data will be taken. Available trait databases will be coupled to the benthic species composition to assess changes. This will allow for comparison of functional differences between benthic communities of areas with and without trawling.

In addition to the existing shellfish survey that samples a large part of the Dutch coastal area (https://shiny.wur.nl/Schelpdiermonitor_Kust/) ten extra trawled dredge samples will be taken just outside the Plaice Box to collect additional samples of shellfish. Age composition and growth rate of shellfish within and outside the Plaice Box will be studied and compared to conclude if differences between these areas exist.

Fish resources

To understand the interaction between food available to fish, benthos composition and consumption of foraging fish, experimental fishing will be undertaken. The experiments will make use of gear similar to the Demersal Young Fish Survey net, such as a shrimp trawl with mesh sizes of 20mm. All specimens caught will be identified, weight and measured and for a subsample of fish, stomach samples will be taken on-board to retrieve diet composition information. It should be noted however that permits to perform stomach sampling need to be acquired which depends on a positive evaluation of request to engage in the sampling. Sampling may be hampered due to the patchy occurrence of bryozoans in the area.

Top predators

Presence of top predators such as seals and birds will be studied based on available tracker data for seals and bird count data from the RWS monitoring that collect counts on a 2-montly interval. No field observations will be made for the snapshot research.

Fisheries

VMS and logbook analyses will be used to calculate the cumulative fishing intensity in the areas by all vessels larger than 12m or equipped with AIS systems for the past 10 years. This information will be used to design the spatial grid to take the box corer samples as well as the trawl hauls. Given that no information at haul level is available, no analyses will be undertaken to differentiate assumed landing composition originating from areas within vs outside the Plaice box for this part of the study.

Analysis of environmental conditions

During the fish resource cruise as described above, environmental conditions such as conductivity, temperature and depth, wind speed, wind direction, wave height and salinity will be measured for each station. These conditions will be used in further statistical analyses to explain part of the variation of the trawl samples. There is no expectation that these environmental conditions will be different within and outside the Plaice box.

Stakeholder consultation

Prior to starting the snapshot research, all stakeholders who have been consulted in the preparations of this phased research approach (Harkes & Steins, 2022) will be informed by email of the planned steps. The results of the snapshot research will be presented to and discussed with the key stakeholder groups: (a) Dutch fishers and organisations, (b) the North Sea Advisory Council, and (c) the Scheveningen Group (or alternatively a focus group of Wadden Sea government representatives)). This will include the question if phase two - Evaluating the **long-term** changes to ecosystem functioning under changes in fishing pressure over time in areas that have remained open and areas that were closed to large trawlers since 1995 – should be pursued or not. In case stakeholders recommend pursuing phase 2, initial recommendations on "do's & don'ts" will be sought. All stakeholders must be informed by the ministry of its final decision.

Reporting & communication

The results of all aspects of the study will be described and summarized in a WMR report. This includes studying apparent differences in ecosystem functioning within and outside the Plaice box. Results will be presented to the client and on invitation of the client to stakeholders. Based on the results obtained, a session will be organised to discuss how results of the different aspects relate, how it improves understanding of the functioning of closed areas and how continued monitoring should be designed to assess the impacts of fishing on the ecosystem.

Logistic details

The area of focus is presented below in Figure 2. There is only a small area of the Plaice box that is within the Dutch EEZ and is situated outside the 12 mile zone. The area denoted with the dark green triangle represents an area with similar natural disturbance, substrate and depth profile (Figure 3, 4). The area has areas with more intense fishing activity inside the 12 mile zone and areas with moderate to low fishing intensity (Figure 5). Depth profile is similar in this area (Figure 6).

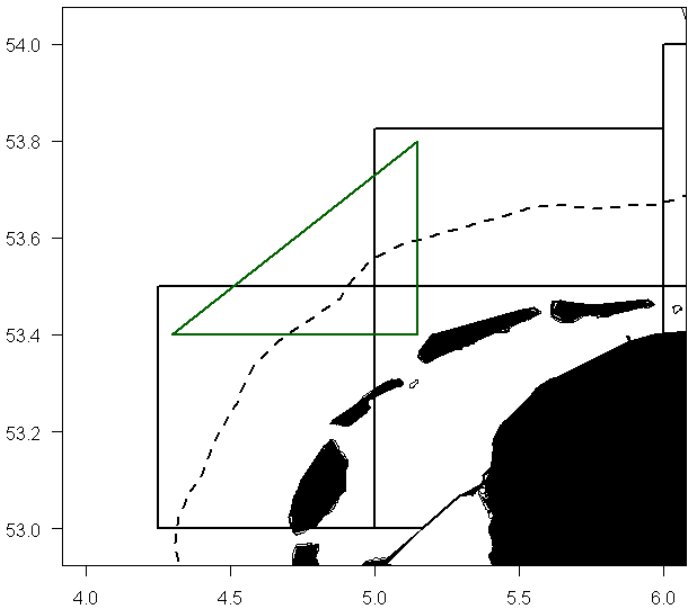

Figure 2. Area of focus for snapshot research denoted by green triangle. The area includes areas within and outside the Plaice box, mostly situated outside the 12 mile zone.

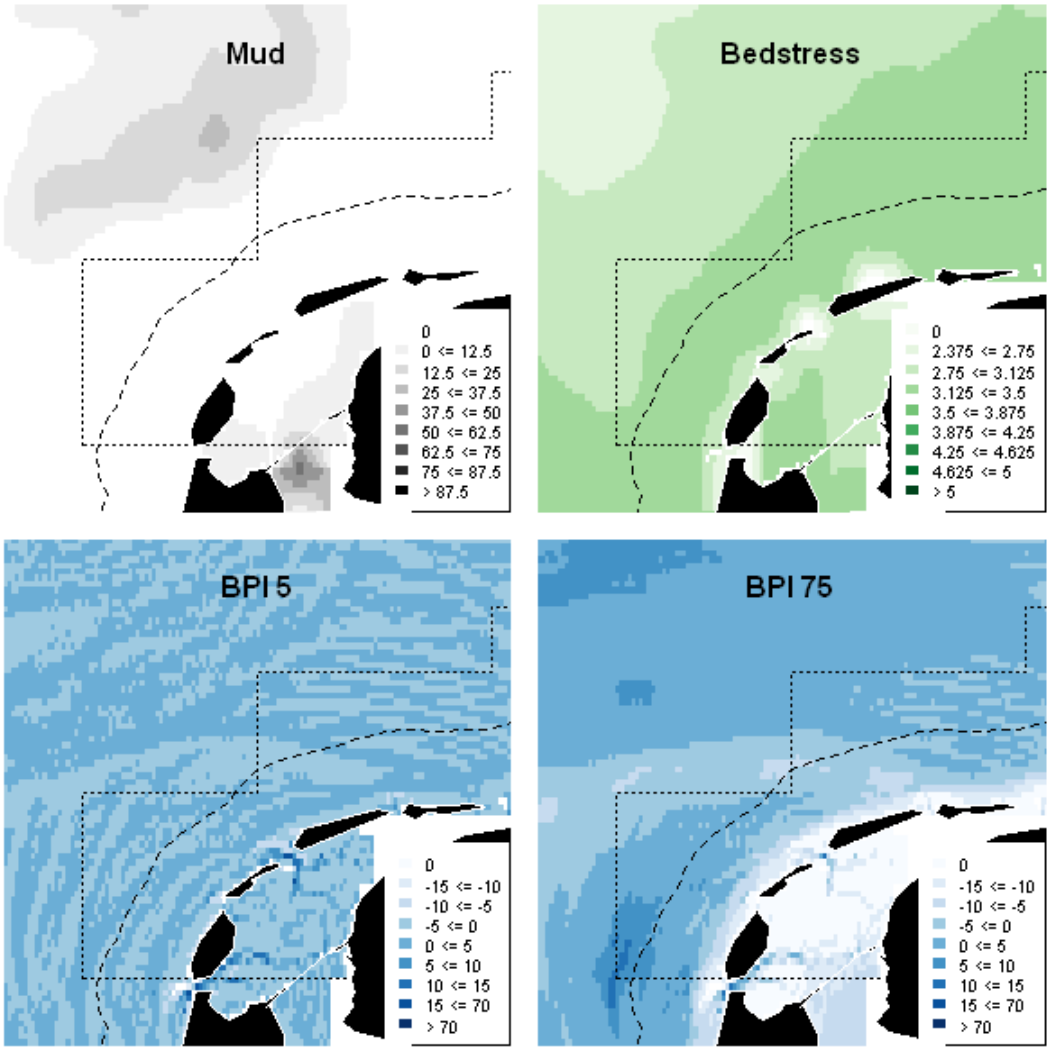

Figure 3. Habitat characteristics of the area of focus for proportion of mud, natural disturbance (bedstress), Bathemetric Positioning Index at small spatial scale (BPI5) and larger scale (BPI75).

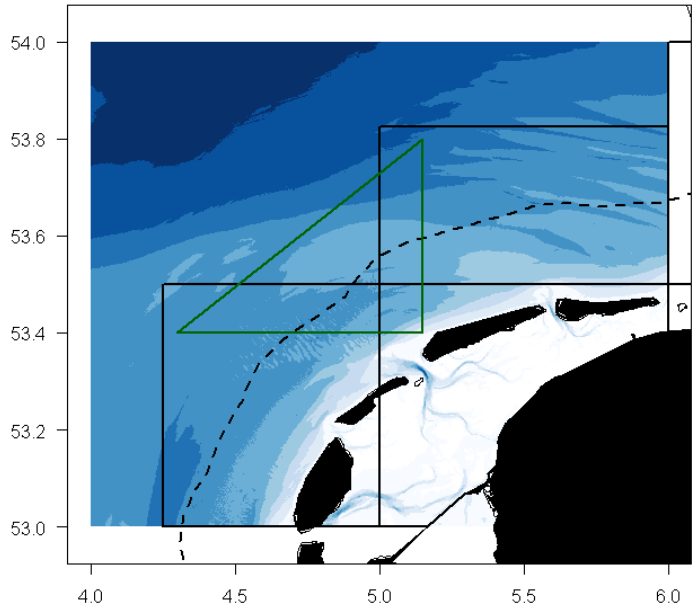

Figure 4. Depth profile for the area of interest

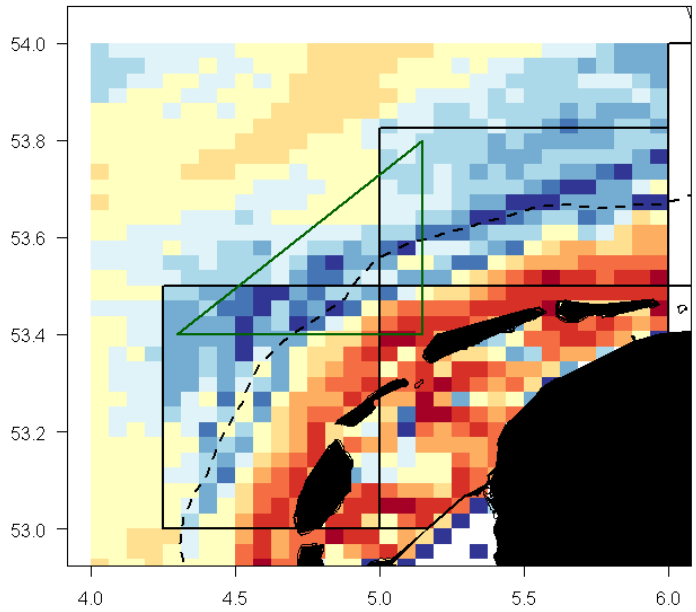

Figure 5. Fishing effort over the years 2012-2021 for all vessels (>12m) in the area at a resolution of 1/16th x 1/16th of an ICES rectangle.

We distinguish 4 different subsets of areas of focus. The area in the lower-left part of the triangle, inside the Plaice box, outside the 12 mile zone. The area in the lower-right part of the triangle, inside the Plaice box, inside the 12mile zone. The area in the upper-right part of the triangle, inside the Plaice box but outside the twelve mile zone and the area in the middle of the triangle, outside the Plaice box and outside the 12 mile zone. The surface area of the area of focus is ~1200km2.

In each of these areas, up to 15 box corer samples and fish trawls will be taken to collect information on sediment, bioturbators, secondary producers, benthos and fish densities. Box corer sampling will take place in spring to avoid recruitment peak of summer while fish resource trawls will take place early summer to match the predominant growth season. Ship time needed to obtain box cores will require approximately 2-3 days at sea. Rough estimates of working days and material expenses are given in Table 1 below.

Table 1. Estimate of working days and material costs for the snapshot research.

	Days	Material	Total costs
Sediment composition	30	12.000	42.000
Bioturbation	15		15.000
Benthic metabolism and nutrient cycles	50	6.000	56.000
Benthic composition	50	67.000	117.000
Fish resources	60	66.000	126.000
Top predators	10	-	10.000
Fisheries	5	-	5.000
Stakeholder consultation	6		6.000
Analysis of environmental conditions	3	-	3.000
Reporting & communication	15	1.000	16.000
Coordination	20		20.000
Total	264	152.000	416.000

Long-term evaluation

To better understand the role of fishing restrictions on ecosystem recovery and anticipated surplus production of fish resources within areas closed to fishing, field experiments are needed. In line with the recommendations in the previous evaluations, including the evaluation of 2010, we here suggest to engage in experimental fishing following a checkerboard design where areas open to fishing are alternated with areas closed to fishing. This implies that certain areas that are currently open to fisheries need to be closed under this design to allow studying how absence of fishing changes recovery of bioturbators, benthic, fish and large predatory marine animals.

A monitoring programme of at least 5 years is foreseen to study the ecosystem changes. During this period there will be extensive monitoring of the full range of trophic levels through new and existing experiments, focusing in the same area as was chosen for the snapshot research. Sampling starts with fishing experiments. Fishing intensity will vary over the different checkerboard cells to study differences in repetitive trawling on ecosystem changes such that areas will only be lightly exploited by a single trawl, some with double and quadruple that amount. Repetitive trawling events will be placed with an interval of approximately a week from each other, similar to the maximum duration of exploitation behaviour of commercial fishing hotspots (Rijnsdorp *et al.* 2011). The experimental fishing trials will therefore take as 4 consecutive weeks. Fishing activity will be limited to beam trawl effort, being the most dominant and destructive fishing technique operated by the Dutch fishing fleet.

Sampling intensity for the experiments relying on box corer samples will be once per year, with two samples per checkerboard cell. This sampling for changes in sediment, bioturbation and benthic metabolism will take place as soon as possible after the experimental fishing event and follows the same outline as described under the 'snapshot' research.

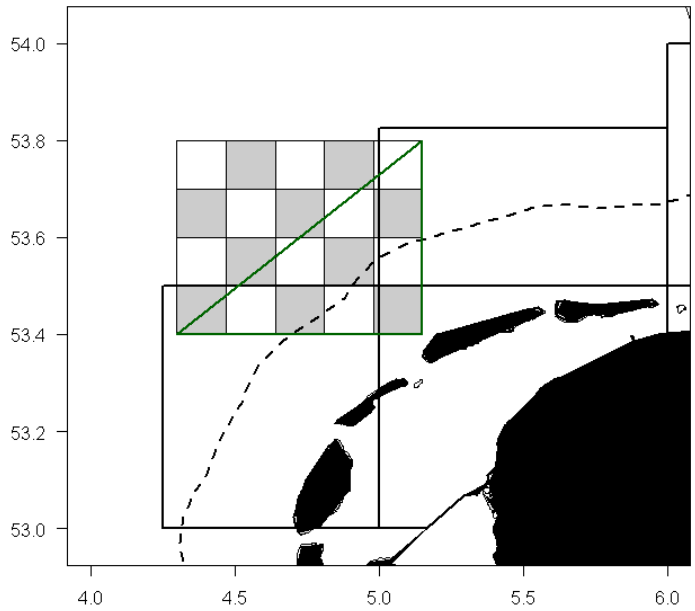

Figure 6. Conceptual checkerboard design for the area of focus to study longer-term changes in ecosystem functioning when fishing is allowed/prohibited. The plaice box is presented by the black solid squares. The 12-mile zone is represented by the dashed line.

Secondary productivy

Secondary productivity will provide insight into the productivity of the Plaice box in comparison to a trawled area just outside the Plaice box. Secondary productivity will be assessed through growth analyses of molluscs. Annual year rings will be counted from molluscs taken from the towed dredge samples as described under the 'snapshot' reseaerch. The samples will be taken just outside the Plaice, where samples from the annual shellfish survey will be used to represent the area inside the Plaice Box.

Fish resources

Trends in changes in the species composition and size ranges captured during the experimental fishing activities will be compared over time for each of the checkerboard cells and further statistical analyses will test for links with changes in e.g benthic composition. The experimental fishing activity will result in haul-by-haul information on fish species compositions where fish will be measured and stomach contents analysed on-board, similar to the approach under the snapshot research. The sampling will provide insight in whether re-opening an area results in higher/lower catches, and bigger/smaller fish and diverse/less diverse species composition.

Top predators

Some change in foraging success and therefore breeding success may be expected for birds nesting at Vlieland when fishing will be allowed again in part of the Plaice box. This change can be offset to breeding success of black-backed gulls and herring gulls populations nesting on Terschelling and Texel. Existing breeding success monitoring by SOVON and NIOZ will be used for this purpose. Changes in feeding behaviour of seals will be studied based on the existing monitoring using GPS trackers with specific focus on differences in spatial preference for checkerboard cells.

Fisheries

Given the experimental setup of the study, no change in fishing behaviour is expected as fishing will take place according to a pre-defined setup. Empirically derived changes in CPUE due to repetitive trawling will be a key result from the trials and provide information on replenishment of fish resource in absence of fishers competition. In addition, catch rates of adjacent cells with identical historic management constraints (in vs outside plaice box, in vs outside the 12 mile zone) will be compared to test if any spill-over effects can be detected over the years.

Stakeholder consultation

Stakeholders will be consulted in preparation of a final monitoring setup to identify any ecological traits that have been, to date, excluded from the setup. Furthermore, industry participation would likely be required for the experimental fishing trials. Buy-in into the process and objectives are therefore needed. Interim results will be presented to stakeholders and reflection on the role of fishing restrictions on ecosystem recovery will be discussed with the aim to derive hypothesis of ecosystem functioning that can be tested through data and statistical analyses towards the end of the project. Final results will also be discussed. Special attention will be given to informing the wider stakeholder group (see under Reporting).

Interim reporting and final evaluation of impact of fishing in and adjacent to closed areas
The results of all aspects of the long-term study will be described and summarized in a WMR report and scientific peer reviewed publications. Short articles on the different phases (start, interim, final results) will be prepared for the fishing newspapers in The Netherlands, Germany and Denmark and Fishing News (read widely by international fishers, NGOs and governments). A project page on the WUR website (Dutch and English) will be created with information on the project and contact details in case of questions/suggestions.Results will be made easily accessible for stakeholders through factsheets in popular language (both English and Dutch), and possibly infographics. The main question to be addressed in the reporting is whether fishing alters ecosystem functioning and the ability of the ecosystem to revert these changes through closed areas. Furthermore the study will address whether it is likely that closed areas have the ability to generate surplus production that spills over the borders of the area hereby providing a status-quo situation for fisheries potential. Where necessary, simulation models will be developed to link the different ecosystem functions and observations. The discussion will furthermore focus on the trade-off between food security, socio-economic relevance of the fishing sector and nature values. Results will be presented to the client and (on invitation of the client) to the stakeholders.

Advice

WMR will contribute to delivering the science base needed for ICES to provide advice on potential re-opening of the plaice box. Results from this study will be brought forward for extensive review within ICES and where needed be supported by workshops that address the role of MPAs for ecosystem functioning in general. WMR will provide scientific support in terms of stakeholder collaboration where needed to the ministry in preparing a political decision on the plaice box reopening.

Logistic details

In each of these checkerboard cells, two box corer samples and fish trawls will be taken to collect information on sediment, bioturbators, secondary producers, benthos and fish densities. Sampling will continue for 5 sequential years.

Rough estimates of working days and material expenses are given in Table 2 below.

Table 2. Estimate of working days and material costs for the long-term monitoring research.

	Days	Material	Total costs
Sediment composition*	150	60.000	210.000
Bioturbation*	75		75.000
Benthic metabolism and nutrient cycles*	250	30.000	280.000
Secondary productivity	100		100.000
Benthic composition*	300	335.000	635.000
Fish resources	600	330.000	930.000
Top predators	50		50.000

Fisheries	15		15.000
Analysis of environmental conditions	15		15.000
Stakeholder consultation	20	1.000	21.000
Reporting & communication	75	5.000	80.000
Preparation of advice	15	2.500	17.500
Coordination	80		80.000
Total	1745	763.500	2.508.500

** Description of activities described under 'snapshot' research*

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